Multifluid Flows, Interface Capturing and Application to the Simulation of the Water Assisted Injection Molding Process

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Abstract

In this paper, we present a 3D finite element approach to compute multifluid flows. Special attention is given to capture the water/polymer interface, that can be obtained used a VOF (Volume of Fluid) or a Level Set technique, with or without adaptative meshing. Results are shown, in for 2D and 3D parts.

1 Introduction

Water Assisted Injection Molding (WAIM) is a recent injection process, similar to Gas Assisted Injection Molding, but that presents a number of advantages: for example, water allows a rapid cooling and a reduction of cycle times; water incompressibility gives higher pressures and more uniform veins. However, the WAIM technique is not well mastered today, and simulation is an important contribution for its development. One of the main problems in WAIM simulation is the inaccurate determination of the water vein position throughout the process. Two different techniques combined with mesh adaptativity will be presented in the following.

2 Water/Polymer interface determination

Placed in an eulerian context, we consider here two types of interface capturing techniques: a Volume OF Fluid (VOF) method and a Level Set technique. VOF methods are obtained by considering the distribution of the volume fraction; the Level Set methods are based on a function from which the level zero traces is the interface that we wish to describe. In both cases the advection equation (1) is used to transport either the volume fraction on each element, or the level set zero, with *v* the velocity field.

$$\frac{\partial \alpha}{\partial t} + v_{convection} \cdot \nabla \alpha = 0 \tag{1}$$

In the case of the *VOF* method, we consider that our computational domain Ω is divided in several subdomains Ω_i. We introduce a presence function associated to each phase, α_i that is 1 if $x \in \Omega_i$, and 0 otherwise. In our case, α_i is constant and can be interpreted as the filled volume over the total volume of the element *K.* Equation (1) represents in this case the transport of a VOF quantity with a convection velocity *v*, and since it is a discontinuous quantity, the Discontinuous Galerkin method is used for its resolution [1]. Even if perfectly conservative, its low order interpolation leads to an important numerical diffusion.

If we consider the interface between two fluids, the *Level Set* technique consists in the introduction of a continuous function α_i where the Level Set 0 represents the interface, and α_i is usually referred as "signed distance" function. The advection equation (1) is then used to compute the isovalues of α. Classical Galerkin schemes are not very adequate to the resolution of pure convection problems, and stabilization techniques as the Streamline Upwind Petrov Galerkin (SUPG) or Residual Free Bubble (RFB) have been used [2]. The Level Set method allows a more accurate representation of the interface than the VOF method, but the solution of the transport equation does not guarantee the distance function property. This is avoided using a reinitialisation scheme.

3 Mesh Adaptation techniques

In order to have a good description of the interface water/polymer, two different mesh adaptation techniques have been used: one concerns only optimal nodal displacement, the other anisotropic remeshing. In the first case, an *r-adaptation* example, the mesh follows the motion of the fluid by contracting the nodes at the interfaces, regaining its original size once the interface passed. The algorithm used is based on a barycentering technique [3]. Details on the mesh obtained, when applying this technique combined with a VOF capturing method, are shown in Figure 1. Another option is to adapt the mesh anisotropically (*h-adaptation*) using a metric field of the form: $M = m^2 A + \varepsilon^2 I$, where $A = \nabla\alpha \otimes \nabla\alpha$, and ε the default size [4]. We can control the number of element layers through parameters m and ε. Figure 2 illustrates the meshes obtained using this kind of approach.

4 Results

4.1 Water/polymer interface capturing through a VOF/r-adaptation technique

In the first example, we consider the water injection phase during the WAIM injection of a tubular part. Interface has been determined using a VOF function, and to limit diffusion, mesh r-adaptation has been used. We can observe that the water vein progresses as expected in the cavity, but that the adaptation scheme is not sufficient to limit the numerical diffusion coming from the VOF scheme.

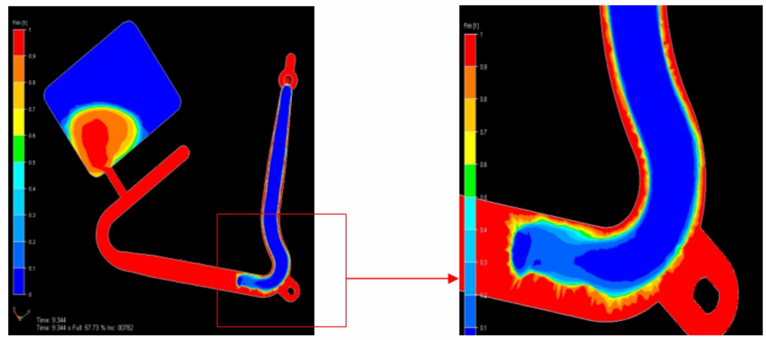

Figure 1: Water injection phase in a tubular part; in blue the water region, we can observe the numerical diffusion (the geometry is a courtesy of the CETIM and of Transvalor).

4.2 Water/polymer interface capturing through a Level-Set/r-adaptation technique

From the results obtained using the previous technique, we have decided to change both the interface capturing method and the mesh adaptation technique. We have considered a simpler 2D geometry, and used the Level Set with remeshing at each time step. We can observe that there is no diffusion has expected, but also that the water vein is accurately determined.

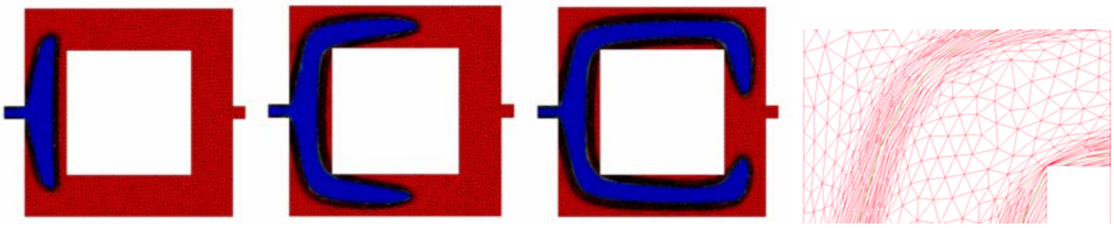

Figure 2: Water injection phase in a simple geometry; in blue the water, and on the right an example on the type of mesh obtained around the interface.

5 References

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